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TITLE: NEW PORTABLE HAND-HELD RADIATION INSTRUMENTS FOR MEASUREMENTS AND MONITORING

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NEW PORTABLE HAND-HELD RADIATION INSTRUMENTS FOR MEASUREMENTS AND MONITORING*

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ISTRACT

ind-held radiation monitors are often used to iarch pedestrians and motor vehicles for special iclear material (SNM) as part of a physical 'otection plan for nuclear materials. Recently, ie Los Alamos Advanced Nuclear Technology group is commercialized an improved hand-held monitor iat can be used for both physical-protection iitoring and verification measurements in nuclear iterial control and waste management. The new initoring instruments are smaller and lighter; ierate much longer on a battery charge; are 'ailable with NaI(Tl) or neutron and gamma-ray insitive plastic scintillation detectors; and are iss expensive than other comparable instruments. iey also have a second operating mode for making 'ecise measurements over counting times as long 99 s. This mode permits making basic verification iasurements that may be needed before transporting iclear material or waste outside protected areas. iproved verification measurements can be made th a second new hand-held instrument that has a abilized detector and three separate gamma-ray iergy windows to obtain spectral information for IM quantity, enrichment, or material-type verifica-.on.

ITRODUCTION

i the early 1970s, the Los Alamos Advanced Nuclear ichnology group developed two small, battery-iwered, radiation detection instruments[1] (Fig. 1) ir hand-held use in searching pedestrians, packages, id motor vehicles for special nuclear materials iNM). The two instruments sense gamma radiation iitted by SNM, which is an excellent but non-visible iue to the presence of the materials. The instru-ints are intelligent; they precisely measure back-'ound intensity and then calculate a detection ilarm) threshold used for monitoring. During initoring, they continuously compare measurements

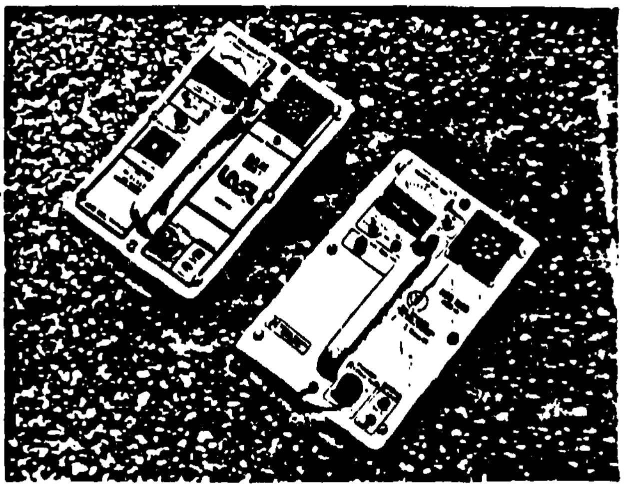

Fig. 1. Two hand-held monitors developed at Los Alamos have been commercially available for many years. The instruments are intelligent and can detect radiation intensities that are a small fraction of background intensity.

with the alarm threshold and sound an alarm (chirp) whenever the threshold is equaled or exceeded. Using one of these instruments, a briefly trained operator easily detects SNM radiation intensities that are a small fraction of background intensity by simply listening for the chirps as he moves the instrument over the person or item being monitored (Fig. 2).

The early monitors are still commercially produced and used for both SNM monitoring and health-physics applications. Another newer monitor having both neutron and gamma-ray sensitivity was developed by TSA Systems, Inc.** and finds similar use. This instrument, the HHD-440 (Fig. 3), uses a large plastic scintillation detector that performs as well as NaI(Tl) detectors but also has sufficient neutron sensitivity for detecting heavily shielded plutonium.[2] However, the HHD-440 has the shortcomings of being heavy, about 3 kg (6.6 lb), and having a short operating time, about 7 hours before recharging, which makes it inadequate for continuous use as a search instrument. These

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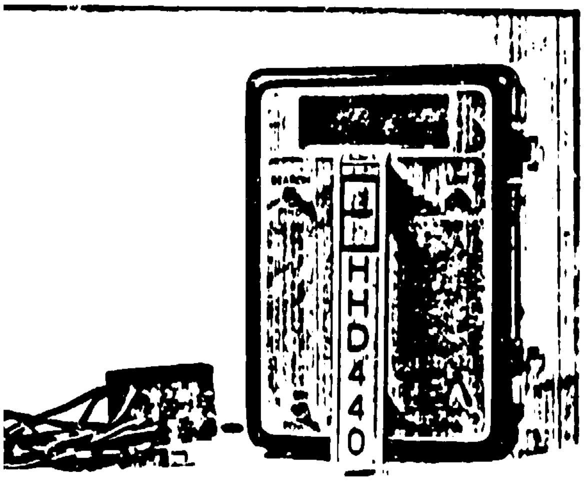
**TSA Systems, Inc., Boulder, CO 80302.

ig. 2. An operator searches for SNM with a und-held monitor by moving the instrument over ll surfaces of a pedestrian, package, or motor hhicle. Successive chirps in a region discloses ie location of SNM.



ig. 3. A relatively new hand-held monitor senses iutrons in addition to gamma rays, making it ffective for detecting shielded plutonium. ifortunately, the instrument is quite heavy and ierates for less than a typical work shift between ittery charges.

iortcomings in an otherwise highly effective and idern hand-held monitor prompted us to commercialize Los Alamos monitor that has the same advantages it is lighter and has a much longer operating me between charges than other hand-held monitors.

THE NEW MONITORING INSTRUMENT

The new Los Alamos lightweight, hand-held instrument is now commercially produced by TSA Systems, Inc. with either a NaI(Tl) or plastic scintillation detector, one of the factors that makes it much more versatile than its predecessors. The new instrument's prototype was developed and described by Millegan and Nixon.[3] Their design goals were to make the instrument lightweight (1.1 kg or 2.4 lb); small in size (about one half the size of its predecessors); low power for long operating time (48 h) on an overnight battery charge (16 h); equal or better in performance than its predecessors; and versatile (two operating modes and an easily reprogrammable microprocessor). TSA Systems designates this new instrument the PRM-470 (Fig. 4) and markets it with one of two operating programs: the Los Alamos 1.01 version described here and a 1.1 version for monitoring only.

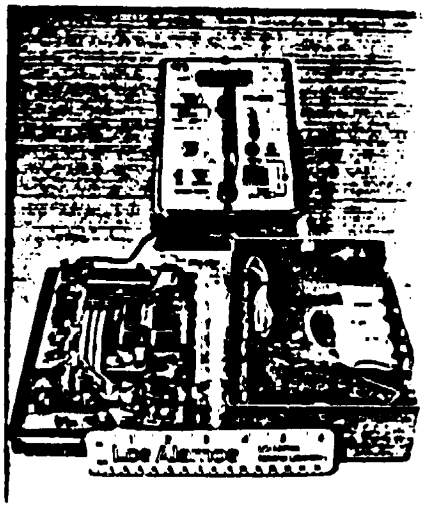


Fig. 4. The new PRM-470 is a recently commercialized Los Alamos monitor. Its light weight, long operating time on a battery charge, and second operating mode for making precise measurements make it the most versatile of the hand-held monitors.

Besides the design-goal improvements, other improvements in the PRM-470 monitor include the microprocessor-generated, auto-ranging count-rate display that shows processed data rather than the output of an independent rate meter found in earlier Los Alamos instruments. The alarm logic[4] is also improved by using a 0.4-s-long moving average of 0.05-s-long counts to improve sensitivity but preserve the fast signal response needed for hand monitoring (0.5-m/s scan speed). The alarm threshold for monitoring is calculated from an expected value derived from the measured background (8-s-long average) plus the number of counts set on the instrument's thumbwheel switch (about 10 to 15 in Los Alamos). Calibration of the new instruments is much the same as in earlier ones, with amplifier gain adjusted to saturate at either 662 or 1332 keV and the lower-level discriminator triggering at about 60 keV.

ll versions of the PRM-470 have the basic advantages f being lightweight and having a long operating ime and choice of scintillator; but the 1.01 version f the operating program offers another advantage. his advantage is a second, switch-selected operating ode (the count mode) for making precise radiation ntensity measurements, perhaps after finding radioctive material with the first (monitoring) mode. r it may be used initially to make brief but recise measurements for SNM verification or other urposes. For example, the author uses the second ode to measure precisely the background radiation ntensity at candidate locations for operating SNM onitors.

n the count mode, the PRM-470 thumbwheel switch s set to a counting time that can be as long as 9 s. Then the instrument repeatedly counts for hat amount of time and converts and displays the esult in counts per second. A significant use of he count mode is to verify that low-density waste ackages contain no more than category III quantities f plutonium (400 g) before being transported outside protected area, perhaps for assay. With a plastic-cintillator instrument, suitable calibration data, and weight screening to assure uncharacteristically heavy materials have not been added to the packages, waste can be verified even though a moderate undetected amount of shielding or other gamma-ray attenuating matrix is present.

The waste verification technique senses shielded plutonium by making filtered and unfiltered measurements with the PRM-470, using a lead attenuator 0.32 cm (0.125 in.) thick between the waste and detector as a filter. If the unfiltered radiation intensity at several positions on the waste container is below a calibrated removal threshold <u>and</u> the filter markedly reduces the count rate, the waste can be removed. Otherwise the waste must be assumed to be a shielded category I or II quantity of material until assayed. Table I illustrates the response of two types of detector to a small unshielded quantity of plutonium and a 100 times larger quantity in a lead shield. The two detectors both show large count-rate reductions with a filter for bare plutonium and much smaller reductions for shielded amounts. However, the NaI(Tℓ) detector ceases to respond to plutonium in thicker shields (where its filtered response falls below background),

TABLE I

PRM-470 RESPONSE TO BACKGROUND AND BARE AND SHIELDED PLUTONIUM

Radiation Source[a]	Filter Type	NaI(Tℓ) Version (counts/s) Gross	Net[b]	Plastic Scintillator Version (counts/s) Gross	Net[b]
Background	none	68.8	0	104	0
Background plus small plutonium	none	208	139.2	316	212
	0.32-cm lead	81.5	12.7	167	63
Background plus large plutonium in 1.3-cm shield	none	233	164.2	518	414
	0.32-cm lead	136.5	67.7	329	225
Background plus large plutonium in 2.5-cm shield	none	80.5	11.7	166	62
	0.32-cm lead	60.5	-8.3	138.5	34.5

[a]The small and large plutonium masses differ by a factor of 100. The shield material is lead.
[b]The net count is the gross measurement with background subtracted.

hile the plastic scintillator continues to respond, emonstrating that it is the best detector choice or this technique. Note that in any case, applying his technique requires calibrating with typical aste and shielded sources to establish realistic ecision thresholds and disclose any limitations f the technique.

he superiority of plastic scintillators for etecting lead-shielded plutonium carries over to NM monitoring. Basic performance data[2] for the RM-470's NaI(Tℓ) detector (diam 2.5 cm and length cm) equal both the earlier monitors' NaI(Tℓ) etector (diam 3.8 cm and length 3.8 cm) and the HHD-440 plastic scintillator (cross section 10.2 by 3.8 cm and length 12.7 cm) for detecting SNM, including lightly shielded plutonium. However, the advantage of a plastic scintillation detector for detecting heavily shielded plutonium is illustrated by PRM-470 measurement results in Table II. The thickest shield in the table reduces the NaI(Tℓ) detector count rate below background, whereas the plastic scintillator continues to detect the shielded plutonium. This advantage in the PRM-470 is provided by its optional plastic scintillator (cross section 3.2 by 7.5 cm and length 10.8 cm), which the manufacturer neatly installs in the same basic package as the NaI(Tℓ)

TABLE II

PRM-470 CONTACT RESPONSE TO SHIELDED PLUTONIUM

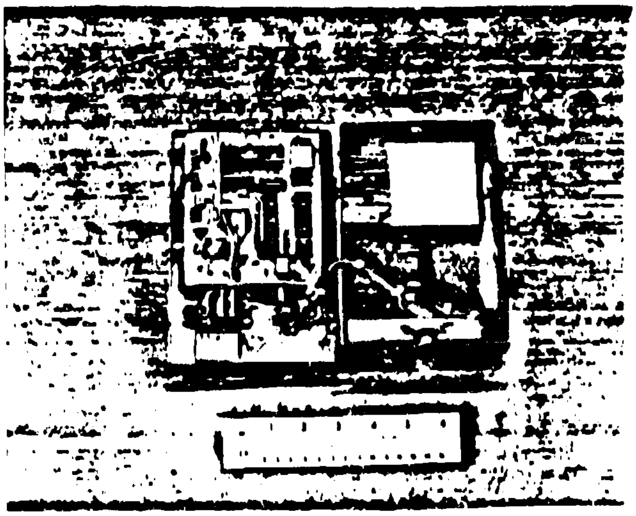
Radiation Source[a]	Lead Shield Thickness (cm)	NaI(Tl) Version (counts/s) Gross	Net[b]	Plastic Scintillator Version (counts/s) Gross	Net[b]
Background	none	64.7	0	103	0
Background plus shielded plutonium	0.95	387	322	901	798
	1.3	104.3	39.7	294	191
	2.5	40.7	-24.0	134.3	31.3

[a]The plutonium has significant self-shielding in addition to the lead shield.
[b]The net count is the gross measurement with background subtracted.

etector (Fig. 5). The plastic scintillator ncreases the PRM-470's weight, but only to 1.6 kg 3.5 lb), about half the weight of the HHD-440, ithout loss of performance.

HE SNM VERIFICATION INSTRUMENT

erification refers to a qualitative technique aving 10% precision as a goal for its result in ontrast to assay, which is a quantitative technique ith perhaps 1% precision as a goal. Verification acrifices precision for speed. Our verification nstrument addresses a long-standing need to quickly erify that radiation emitted from packages, fabri-ated items, or even pedestrians is or is not charac-eristic of a specific type or quantity of SNM. xamples of the need to verify are (1) to determine the presence or absence of plutonium in radioactive packages; and (2) to verify the enrichment, low or high for example, of uranium items.

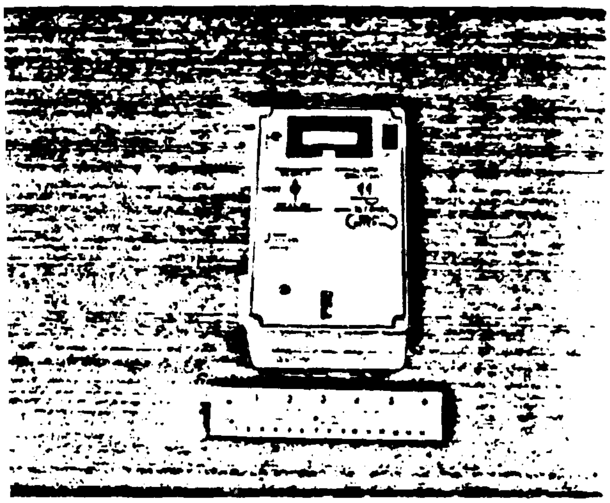


ig. 5. The optional plastic scintillation detector ives the PRM-470 both neutron and gamma-ray ensitivity. Neutron sensitivity makes it possible o detect shielded plutonium in monitoring and erification.

An earlier hand-held instrument developed by the Los Alamos Instrument Technologies group, the Automatic Material Identifier,[6] identified bare uranium and plutonium from recorded spectra of low-energy gamma rays. Because the low-energy radiation may not be clearly observed when SNM is well encapsulated, shielded, or mixed with other radio-isotopes, another technique must be used. Often a thicker detector is used with a portable multichannel analyzer to record spectra of penetrating, higher energy gamma rays for further analysis. For example, gamma-ray peaks characteristic of uranium or plutonium may be recorded, stripped from an underly-ing Compton-scattered gamma-ray background by a utility program, and then integrated to obtain a net peak count contributed mostly by SNM radiation. The peak count then may give a good indication of the presence, absence, or mass category of SNM or the enrichment of uranium that cannot be obtained from gross measurements or the original spectra. Our new hand-held SNM verification instrument is designed to perform this task in a package that is not much larger or heavier than the PRM-470 described above.

The prototype SNM verification instrument is being fabricated for us by Jomar Systems, Inc.* as model JHH-01 (Fig. 6). In contrast to the gross counting in hand-held monitors, peak stripping requires a gain-stabilized detector so that gamma rays always fall into specific pulse-height regions of interest. The region of interest data are used with an enhanced computational ability to carry out a variety of tasks including: verifying nuclear material type or enrichment during inventory or shipment, verifying the absence of plutonium in ped-estrians with medical isotope uptakes, and verifying the plutonium mass category of waste containers. Of course, in this case, calibration of the technique with typical items and a continuing measurement control program are also necessary for effective use of the technique.

*Jomar Systems, Inc., Los Alamos, NM 87544.



. 6. *The JHH-01 is another new Los Alamos trument being produced by Jomar Systems, Inc. will perform verification measurements that ally require less portable instrumentation.*

the time of writing this report, the mechanical electrical work on the JHH-01 is complete, but gramming is still in progress. So, our examples applications data were obtained with PRM-470 truments and an IBM-PC-based multichannel lyzer. The first example identifies the presence plutonium shielded by depleted uranium, a radioac- material that is commonly used in source-shield- containers (pigs). Here the pig is 0.5 cm :k and produces most of the detected radiation. ever, stripping the prominent plutonium region ween 330 and 450 keV (Fig. 7a) from the empty spectrum (Fig. 7b) and the pig plus plutonium :trum (Fig. 7) gives significantly different ilts. The net count for the pig alone is minus) ± 7.6 counts/s, whereas the result is plus) ± 8.6 counts/s for the pig containing plutonium. :e, the presence of plutonium is detected even igh it would give no readily visible clue in a gle spectrum. This example is typical of what involved in identifying plutonium in mixed :e or in identifying the absence of plutonium :adioactive packages. Note that the instrument is available only the final result, a net count, ier than a plot of the spectrum. While this is the technique more sensitive, calibration measurement control are more important to its ective use.

:her example illustrates verifying pellets that be natural or depleted uranium. The larger : in the highly enriched uranium spectrum (Fig. is the 185-keV gamma ray from ^{235}U. When this : region is stripped and integrated, the result natural uranium (0.7% ^{235}U) in Fig. 8b is 2669, eas the result for depleted uranium (0.2%) in Fig. 8c is 1420. Hence, the two materials be differentiated provided that the technique been properly calibrated and controlled.

des these single region-of-interest examples, instrument is designed to be able to duplicate r methods for determining enrichment that are

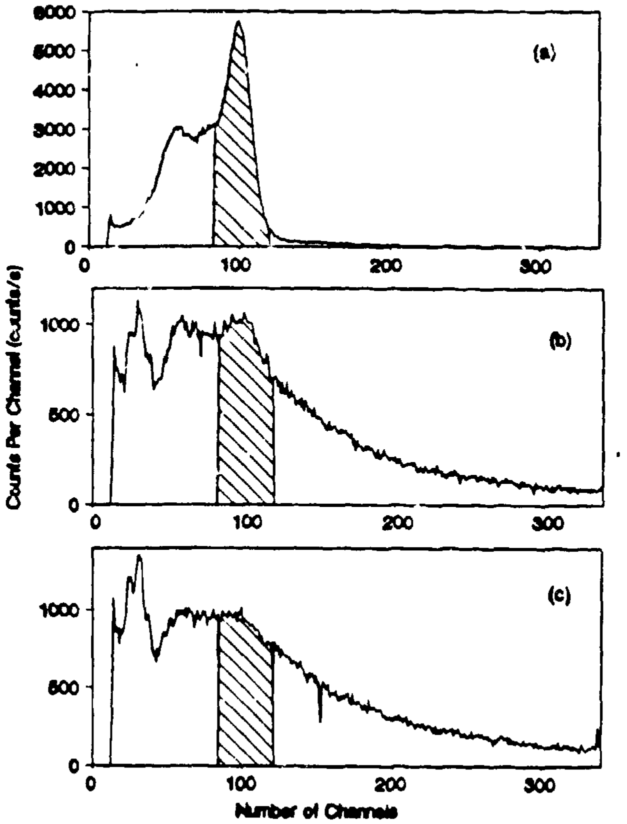
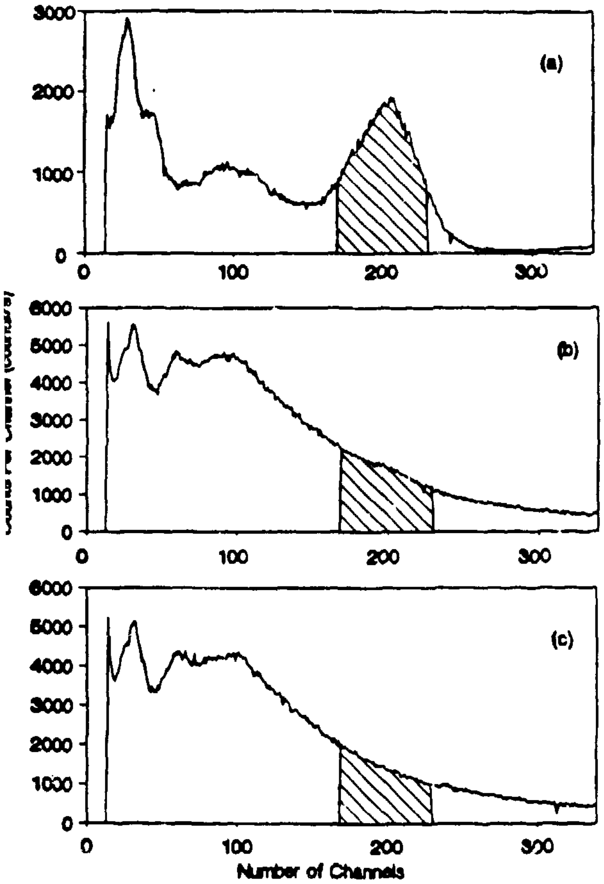


Fig. 7. These spectra illustrate plutonium verification in a mixed radiation field: (a) the plutonium spectrum; (b) spectrum from depleted uranium pig; and (c) spectrum from pig containing plutonium. Highlighted areas contain penetrating plutonium gamma rays (a) plus other radiation (b) and (c).

less sensitive to the size and shape of samples. For example, a region of interest around 766 keV or 1001 keV can be used with the 186-keV region to give the intensity ratio used in one enrichment technique.[8] Another technique that can be implemented uses the 186-keV region and a nearby higher energy region plus certain calibration constants to correct for Compton scattering and give enrichment directly.[4] Practical experience in applying the instrument to these techniques awaits completion of the programming.

SUMMARY

The new lightweight hand-held instruments have the potential to improve hand-held monitoring, particularly for detecting shielded plutonium, and the instrument's second operating mode expands their utility to other applications such as verifying waste. Both new techniques and others that are now routinely applied with less-portable equipment can be readily accomplished with minimum effort. The most effective use of the instruments will be



'ig. 8. These spectra illustrate uranium verifica- ion enrichment: (a) the ^{235}U spectrum; (b) atural uranium spectrum; and (c) depleted uranium pectrum. Highlighted areas contain ^{235}U gamma-rays a) plus other radiation (b) and (c).

btained in a program that conducts calibration xperiments to determine appropriate decision hresholds and then follows a program of measurement ontrol tests with standard items to assure proper peration. Finally, effectiveness of the new nstruments will certainly depend on their proper se and good operator training.

ACKNOWLEDGMENTS

Many members of the Advanced Nuclear Technology group are to be thanked for their efforts to develop three generations of prototypes for the new hand-held monitor. TSA Systems, Inc. developed a comparable monitor, the PRM-470, from the prototype design but used a new microprocessor, an NSC800N, and their own programming. Jomar Systems developed the detector stabilization method and practical means to change operating parameters for the new verification instrument as well as providing software.

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